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Director's Notes

It was about eight years ago that I was sitting in a small classroom at the Naval Postgraduate School in Monterey, California taking a class on aircraft survivability from a professor named Robert Ball. At the time, I had no idea as to the extent of the aircraft survivability world, all the talented professionals involved, nor did I appreciate the fact that I was being tutored by one of the pioneers of aircraft survivability. Since I was a P–3 Naval Flight Officer, I gave little thought to aircraft survivability. Why do I say that? Well, we rarely flew near land, we avoided hostile surface forces, we spent most of our time hunting vessels that we never even saw, and we flew at low altitudes in a big and slow target. Most P–3 aircrew assumed that the probability of being shot was extremely small, and if we did get shot, we would not survive. If by some chance, a submarine or small fishing boat launched a shoulder-fired missile at us, there was not much we could do.

Now it is many years later and I am the Director of the Central Office of the Joint Technical Coordinating Group on Aircraft Survivability. When I was offered this job, I honestly had no idea what the organization was about or the extent of the work they did. However, the idea of working in the aircraft survivability field was extremely appealing because I knew it would allow me to learn about all types of aircraft from all services. I have since been reintroduced to all of the numerous aspects of aircraft survivability and all the work being done and I consider it an honor to work with some of the most talented, conscientious, and capable members of DoD's technical community.

I am not, however, the only new member to the JTCG/AS team. I would like to extend a cordial welcome to Mr. Larry Miller as the new Acting Deputy Director for Live Fire Test and Evaluation within DOT&E, which is the OSD sponsor of the JTCG/AS. For the last ten years he has been the DOT&E Action Officer responsible for oversight of missile defense systems. Mr. Miller continues to be responsible for oversight of the ballistic missile defense programs as well as serving as the Director of LFT&E. Even though he is extremely busy, the JTCG/AS has been fortunate to have had several opportunities to brief him on our program. It is obvious that he will be a strong supporter of the JTCG/AS and we are looking forward to building a lasting relationship between DOT&E and the JTCG/AS.

Mr. Miller spent much time reviewing the numerous projects that we sponsor each year, and had very specific comments about many of our activities, including the newsletter. He said that many people read *Aircraft Survivability,* but still have don't really know what the JTCG/AS actually does. He suggested we spend more time in the newsletter focusing on the ongoing programs of the JTCG/AS and all the successes that have resulted. With this in mind, I have made it a priority for *Aircraft Survivability* to spend more time publicizing the merits of this invaluable organization and its programs. We cannot completely do this in a single issue of the newsletter. Rather we will highlight several JTCG/AS projects in this and future Aircraft Survivability newsletters with the goal of informing the survivability community on advanced technologies and methodology improvements, as well as on our connection to the warfighter.

This issue of *Aircraft Survivability* reviews several very promising JTCG/AS projects that are ongoing. The first of these articles on passive fire protection, shows some excellent work being done by Joe Manchor at China Lake Naval Weapons Center as well as Mike Bennett at Wright-Patterson AFB (WPAFB). Joe and Mike are two of the co-chairmen of our Fuel Systems Committee under the Vulnerability Reduction Subgroup. Joe has demonstrated several low cost, low weight, methods for extinguishing internal aircraft fires, which could revolutionize the way future fire suppression systems are designed and procured. Mike's project is demonstrating new innovative hot surface ignition mitigation techniques. Next, Dr. Lenny Truett of the USAF 46th Test Wing at WPAFB provides some insight into the future of Aerogels. Aerogels have shown promise of being a remarkable IR suppression device that can be quickly applied to existing aircraft of all types. Another article by Nick Calapodas from the Army Aviation Applied Technology Directorate at Fort Eustis, describes the MANPADS Ballistic Test of a Helicopter Composite Generic Tailboom project. This project illustrates the JTCG/AS' ongoing commitment to reduce the MANPADS threat to all types of aircraft, espe-

cially rotorcraft. These three projects demonstrate the diversity of the JTCG/AS mission, and these projects are tri-service and cross-platform.

Another example of the diversity of the JTCG/AS is the focus, not only on aircraft survivability, but also on spacecraft survivability. Having just transferred from the National Reconnaissance Office (NRO), I am anxious to again have the opportunity to be involved in the spacecraft design world and look forward to possibly expanding the role of the JTCG/AS into the spacecraft survivability community. Furthermore, spacecraft survivability is a field that is still relatively new and there appears to be a synergistic approach between aircraft survivability design and spacecraft survivability design. This presents a tremendous opportunity for the JTCG/AS. The problem is, not everything translates easily from aircraft design to spacecraft design. So this is an area that needs to be explored because the possibility exists for a large amount of cross-fertilization between the two fields. We could potentially achieve great results at little cost by applying aircraft survivability design tools and techniques to spacecraft survivability design. Because of this, the JTCG/AS has a responsibility to at least explore the spacecraft survivability design discipline. Last August, we took another step in integrating efforts of the two communities by co-sponsoring the Air and Space Protection Conference at the U.S. Air Force Research Laboratory at Kirtland AFB, New Mexico. This workshop provided experts from both the aircraft and spacecraft survivability fields the opportunity to exchange information on current survivability efforts and explore future collaborative efforts. While the conference was a good start to forming a coalition between the two communities, much work remains to be done. We still have a long way to go, and don't know what the end result may be, but we certainly are off to a good start.

In summary, I am happy to be involved with the survivability community and look forward to continue meeting members of the community. I am also very interested in making *Aircraft Survivability* the most informative publication I can. If you have any comments or suggestions, please E-mail me at Cibulaal@navair.navy.mil. We may even put your comments in the next issue.

LCDR Andrew (Andy) Cibula (USN)
Director, JTCG/AS Central Office

Protecting Space Services

by Mr. James D. Rochier

In light of U.S. dependence on vulnerable space assets, it would be contrary to U.S. security interests not to develop, test, and deploy a means of deterring attacks on, and defending, space systems.

—The Honorable John P. Stenbit, Assistant Secretary of Defense (Command, Control, Communications, and Intelligence) in written testimony during his July 31, 2001 confirmation hearing

Every day we become more reliant on space systems to execute our critical national security missions. And even as we become more reliant, our systems become more vulnerable due to a rapidly evolving threat. Even today, there are scores of threats—capable of denying, disrupting, and even degrading our ability to provide these critical services. The number and kinds of threats will only increase in the years to come. Senior leaders in both the Government and industry have begun to recognize the disparity in our dependence and protection stance, and many have echoed the call from the Commission to Assess United States National Security Space Management and Organization to prepare for a "space Pearl Harbor." While organizational changes are being put in place, there are still significant technical challenges that must be overcome to facilitate protecting space services.

To meet these challenges, the U.S. Air Force has developed and evolved a doctrinal framework for space control, including the defense of space services. This doctrinal framework defines space control as "the means by which space superiority is gained and maintained" [AF Doctrine Document 2–2 (AFDD 2–2), Space Operations]. This doctrine goes on to define three contributing capabilities—space situational awareness, offensive counterspace, and defensive counterspace. For those who are familiar with air superiority doctrine there should be a ring of familiarity in these capabilities. Defensive counterspace is further developed in AFDD 2–2 into active and passive components. Active defenses are those actions taken to defeat an enemy counterspace force—operations such as maneuvering, deploying decoys, or employing lethal methods to neutralize a threat. Passive defenses are those measures taken to make the system less vulnerable such as redundancy, shielding, applying optical filters, or improving the jam resistance of a communications link.

You may have noticed the use of the term "space service" rather than "space system." While the protection of expensive, and sometimes irreplaceable, space hardware is important, the real goal is protecting the services those space assets provide. This allows us to consider a wider range of protection options, and insures that we don't forget the critical launch, ground, and communication link elements that are often the weak points in our defense posture.

The challenges facing us in developing a robust protection position are wide-ranging. There are cultural barriers—despite indications to the contrary, many believe that space is a sanctuary. This (often subconscious) belief has led to the proliferation of many unprotected or under protected systems. There are also legal barriers. While the U.S. Government has made it explicitly clear that an intentional attack on or interference with our space systems is an infringement of our sovereign rights, it is not clear what our response might be, and it is even less clear that international law and treaties would support all of the possible responses we might consider. There are also blurred roles between defensive counterspace and defensive counterinformation. This, along with several other unclear organizational responsibilities sometimes creates unnecessary or non-optimum technical interfaces driven by organizational boundaries. The coordination of an active response is a challenge that has not yet been fully met, but one that will

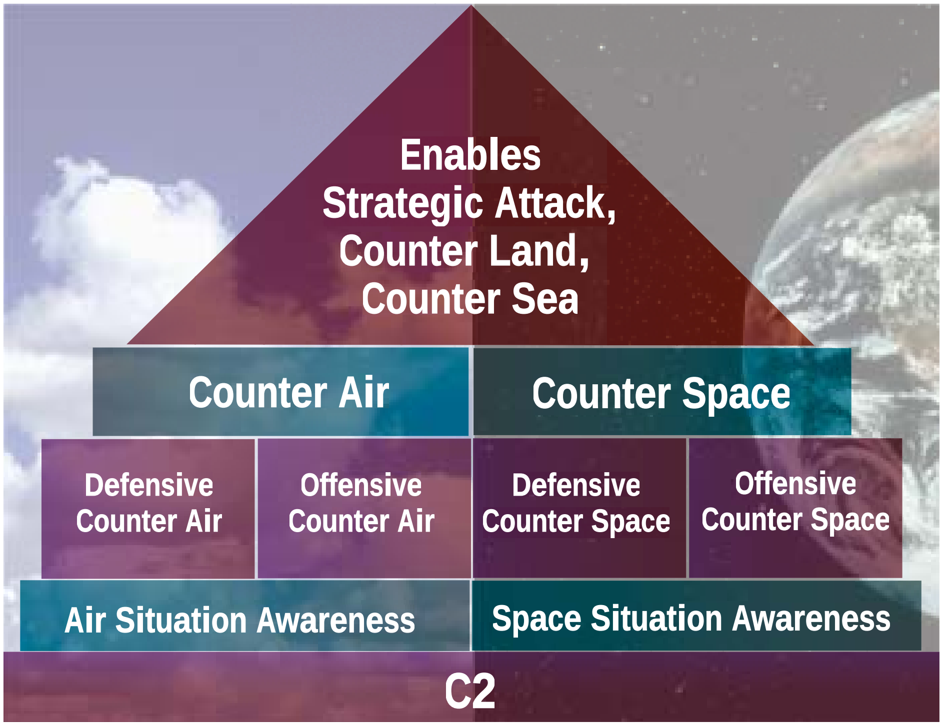

Figure 1. Doctrinal Relationship

be attempted during the upcoming Joint Expeditionary Force Exercise for 2002 (JEFX02).

On August 29–30, The Association of Old Crows, the U.S. Air Force Research Laboratory, and the JTCG/AS sponsored the 3rd Air and Space Protection Conference at the U.S. Air Force Research Laboratory, Kirtland AFB, New Mexico. This group was challenged to build a forum for discussion and provide a nucleus of professionals interested and/or working in this area. Topics included threats to spacecraft, requirements for protection of spacecraft, space and air integration, guidelines for protection, modeling and simulation tools, and ongoing protection development programs. Over two days, the attendees heard presentations on 29 topics covering the broad scope of the theme. Presentations ranged from the potential application of proven and leading-edge aircraft survivability techniques to space systems' protection, to ongoing space protection experiments, to ongoing plans and protection programs.

These technical and programmatic discussions fit well into the space protection mission and its key elements—controlling knowledge, threat deterrence, attack detection, survivability, and rapid recovery. At the U.S. Air Force Space Command, a new architecture for the detection and characterization of space system attacks is just beginning its deployment. This new system, the Rapid Attack Identification and Reporting System is simultaneously conducting an Analysis of Alternatives and beginning deployment of the satellite as a sensor concept. Alternatives under consideration include on-board and off-board detection and characterization sensors, centralized and distributed processing approaches, and automation of data processing and fusion to reduce the ambiguity of detection and characterization. At the same time, improvements in space system survivability are under development.

As the attendees at this year's Air and Space Protection Conference can attest, the importance of space services to our warfighters, to our economy, and to our national security in general cannot be overemphasized. We are in the midst of a paradigm shift and we are fortunate to have senior leaders who are aware of the importance of the mission and who are providing the leadership and resources to insure its success.

Mr. James Rochier is a Senior Project Engineer with The Aerospace Corporation, Space Applications, Requirements, and Applications division. He earned a B.S. and an M.S. in electrical engineering from the University of Texas, Arlington in 1986 and 1987, respectively. He is pursuing an M.S. degree in software systems engineering from the University of Colorado, Colorado Springs.

New Concepts in Passive Fire Protection

by Mr. Joseph A. Manchor

Fire can be the leading contributor to the attrition of aircraft in combat. Autonomously activating "active" fire suppression systems are the most effective means of providing protection against fire. Unfortunately, active fire suppression systems can be complex, with numerous subsystems including fire detection, alerting, and activation, along with suppression agent storage and distribution subsystems. As the complexity of these systems increase, so do their potential for false alarms and/or failure. They can also become unacceptably costly and heavy. As a result, some aircraft programs have been forced to consider alternative solutions to their fire problem.

Passive fire protection technologies are usually preferred due to their inherent low cost and weight. However, a myopic focus on the cost and weight benefits of a passive system may result in overlooking the actual effectiveness of the technology. In reality, passive fire protection technologies have changed very little over the years, with some having questionable effectiveness in certain environments.

The Fuel Systems Committee (co-chaired by Joe Manchor—NAVAIR, Mike Bennett—USAF 46th TW, and Fred Marsh—USA ARL) of the JTCG/AS has recently concentrated on enhancing the effectiveness of passive fire protection technologies. The intent is to reduce the cost and weight penalties normally associated with effective fire protection. Projects include improving current passive technologies, along with developing entirely new technologies. The following is a brief review of some of the fire protection work proposed or currently under development by the JTCG/AS.

Simple Passive Extinguisher

The Simple Passive Extinguisher (SPEX) concept may provide an effective alternative to an active fire suppression system. The concept focuses on system simplification, eliminating the subsystems normally associated with active suppression systems. A reactive agent is placed or installed directly within the aircraft compartment to be protected. The characteristics of a fire, such as heat, will initiate activation of the agent so that it rapidly fills the compartment and extinguishes the fire.

Commercial off-the-shelf (COTS) technologies already exist that can be applied to emulate this concept. However, emerging technologies and agents promise ideal application of the concept. An example agent could be Bis-aminotetrazolyl-tetrazine, or BTATZ for short. BTATZ is a solid compound that decomposes primarily to nitrogen gas once initiated by heat. This decomposition is rapid, self-sustained, flameless, and occurs readily at most pressures. The nitrogen gas serves to displace oxygen, thus extinguishing a fire.

BTATZ could be installed near fire vulnerable areas, and would be expected to react and initiate from the heat of a fire, thus extinguishing it. BTATZ installation could be in lightweight, heat conductive, protective packaging (such as vacuum packed foil), or even no package at all (such as in

Figure 1. BTATZ Fire Suppression Paint

paint form). Figure 1 (see page 7) illustrates a BTATZ paint developed under JTCG/AS project V–1–04 "Passive Fire Mitigation Technologies—Reactive Powder Panels."

Reactive Powder Panels

This JTCG/AS project is investigating mechanisms to enhance powder release from commercial fire protection powder panels. The current technology utilizes brittle panel structures that are filled with a fire suppressant powder. These panels are installed within a compartment to be protected, adjacent to internal aircraft fuel sources. Ballistic impact will break open a panel, releasing some of the encased fire suppressant powder.

In many cases, very little powder may be released from ballistic impact, limiting the technology's application to small compartments with little or no airflow. To increase effectiveness, application of powder panels must usually be combined with another means of passive fire protection, such as self-sealing fuel cells, at considerable cost and weight penalty.

The enhancement concept is simple, and is based upon "painting" a thin layer of a reactive energetic material (such as BTATZ) on a backing board surface. A commercial powder panel is then affixed to the backing board, effectively "sandwiching" the energetic between the panel and the backing board. The completed fixture may then be installed within the compartment to be protected.

Figure 2 illustrates the concept. Upon projectile impact, the energetic initiates, rapidly releasing large amounts of inert gas. The backing board absorbs and directs much of the expanding gas' energy toward the brittle powder panel. The panel breaks up, and is ejected outward, releasing most of its fire suppressant powder (mixed with inert gas) into the compartment.

Ionomer Fuel Containment

An ionomer is a polymer that contains ionic groups. These ionic groups are attracted to one another to provide a non-permanent cross-linking. Cross-linking is a mechanism that provides strength within a polymeric material.

The cross-linking properties of ionomers produce a unique self-healing capability for certain applications. Ballistic penetration may impart enough heat energy to an ionomer to separate the ionic groups and cross-linking, making the wounded region temporarily a very pliable elastomer. As the wounded region is cooled by the ambient conditions, the ionic groups reattach, producing a "healed" state. This ability may offer aircraft designers an improvement over current fuel self-sealing technologies. Ionomers may also prove to have potential use in other fluid containment applications, such as hydraulic or lubrication fluids.

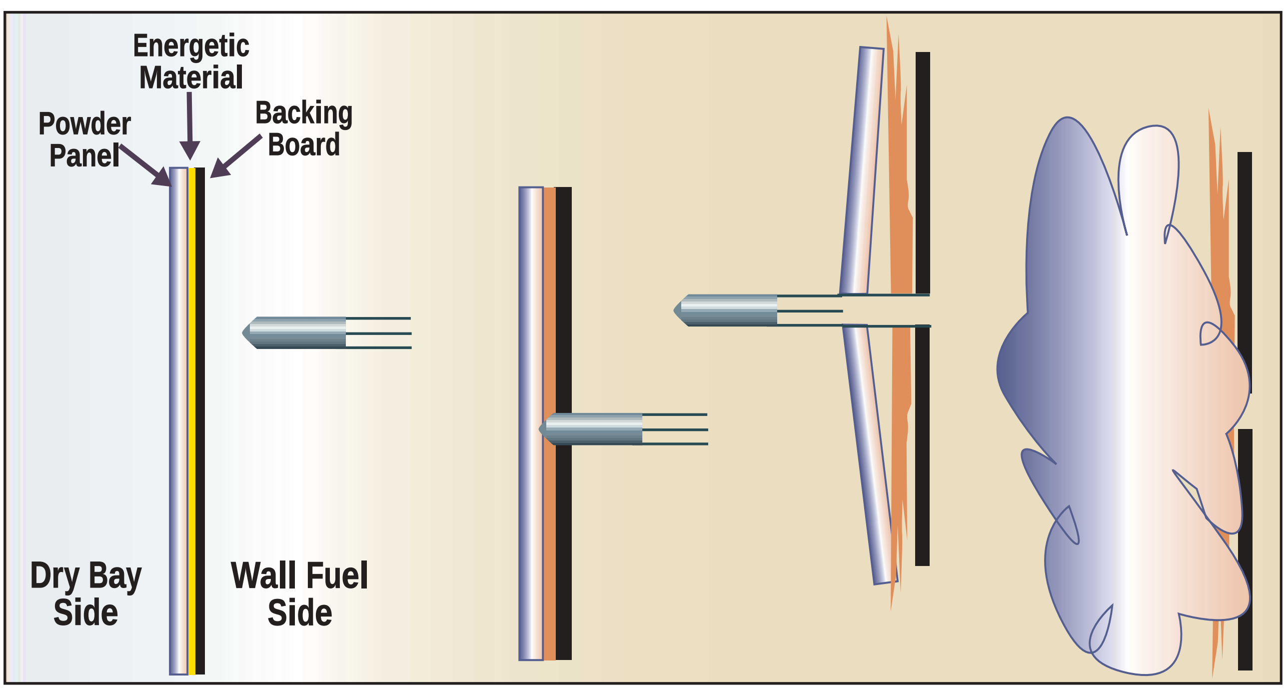

Figure 2. Reactive Powder Panel Enhancement Concept

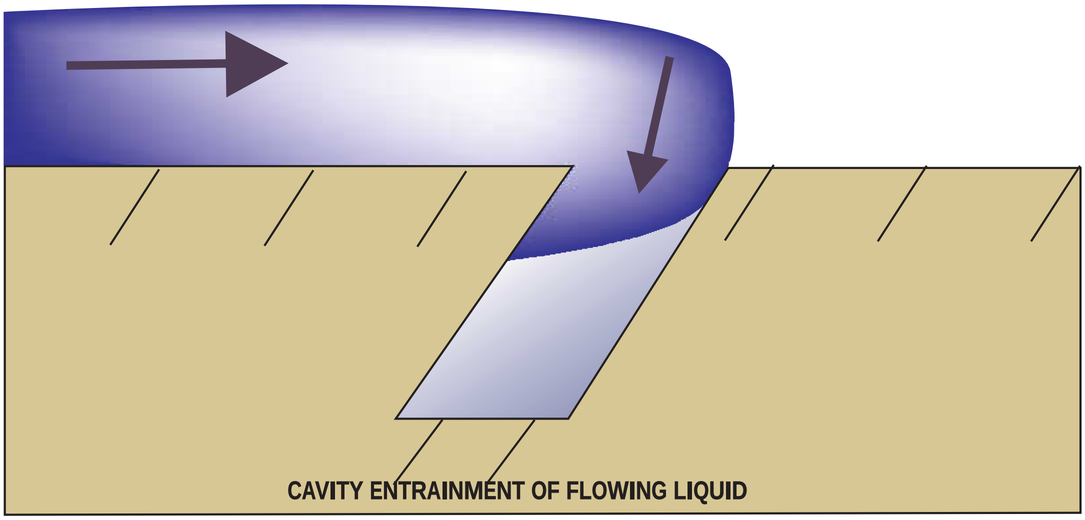

Figure 3. Incorporating a pattern of micro-cavities on the other surface of a hot component.

Hot Surface Ignition Mitigation

Flammable fluids will often ignite when they encounter hot components such as bleed air ducts, engine surfaces, and other hot operating components. These incidents result in formidable fires that are very difficult to extinguish. This JTCG/AS project will spin off prior research into a program to identify an appreciable increase in safe operating temperature for heated components without the observed presence of ignition.

A possible technique entails the incorporation of a pattern of micro-cavities on the outer surface of a hot component (see Figure 3). These micro-cavities could be rolled, stamped, or otherwise added to the component during manufacture. The cavities are sized such that when a leaking fluid spreads across the hot component, the liquid seals off the cavity to entrap a pocket of air, thereby reducing the direct surface-to-liquid heat conduction. The reduction in heat transfer results in less liquid vaporization in sufficient levels to reach the lean flammability limit and ignite. This ignition mitigation behavior allows the adoption of hotter operating temperatures without the threat of ignition. This technique should not add weight, and may in fact reduce component weight, while only requiring an inexpensive operation during manufacture.

Intumescent Firewalls

Lightweight intumescent materials respond to fire impingement by swelling several orders of magnitude beyond their original thickness. This swelling forms a protective char that thermally protects and insulates structure. This JTCG/AS project will demonstrate and optimize the utilization of intumescent technologies to form instant firewalls to control, contain, and manage damage-related fires in compartments.

Intumescent material can be applied as very thin strips to structure or on machinery at locations where clearance is minimal. Fire induced swelling could block off the clearance and restrict the downstream airflow path in the vicinity of a fire. This may deprive the fire of a steady flow of oxygen, and possibly facilitate self-extinguishment. If an extinguishing system is also used, its effectiveness might be improved because of the weakened fire condition and the reduced airflow dilution of the extinguishant.

Mr. Manchor is an aircraft vulnerability reduction engineer at the U.S. Naval Air Warfare Center Weapons Division (NAWCWD), China Lake, California. He has conducted numerous live fire ballistic tests of naval aircraft, and provided subsequent recommendations to reduce the vulnerability of these aircraft based on the results of testing. With a specialty in aircraft fire and explosion protection, he oversees and conducts research and development efforts in this field. He serves as chairman of the NAWCWD Fire Science and Technology Panel, and co-chairs (with Mike Bennett USAF 46th TW, and Fred Marsh USA ARL) the Fuel System Committee of the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS). He holds a Masters degree in Mechanical Engineering from the Pennsylvania State University ('94), and a Bachelors degree in Aerospace Engineering from the United States Naval Academy ('81). He may be reached at manchorja@navair.navy.mil

An Insight Into Aerogels—Past, Present, and Future

by Dr. Leonard F. Truett, III

Figure 1. Transparent Aerogel

The definition of an aerogel is simply a 3-dimensional solid structure in a lattice structure with nanometer sized pores. The resulting substance can be over 99 percent void space, but the pores are so small that gasses cannot flow freely through them. In fact, the pores are so small that gas molecules cannot freely vibrate. The production of aerogels involves two processes— the preparation of the wet gel and the drying of that gel. Most modern aerogels are created using a mixture of silicon and an organic compound (e.g., ethyl alcohol). After the wet gel is created, it is flushed with liquid $C0_2$ and then the mixture is raised beyond its supercritical point (a specific combination of pressure and temperature) where it exhibits some properties of a liquid and some properties of a gas. This allows the fluid to boil out gently without tearing the cell walls. A simplified example of this process would be making Jell-O, and then removing all of the water without destroying the gelatin structure.

Aerogels were first created in the late 1920's by Steven Samuel Kistler. In the early 1940's he licensed the manufacturing process to Monsanto Corporation. Sold under various trade names, these silica aerogels were used in cosmetics, toothpaste, paint and even napalm. After the development of low cost fumed silica in the 1960's, Monsanto ceased production.

Aerogels were largely forgotten until the late 1970's when there was renewed interest in their unique thermal properties. Over the next 15 years, there were several improvements in the manufacturing process that made aerogels safer, faster, and cheaper to produce, but they were still not economically viable on a large scale. Then in 1999, Aspen Systems won the Small Business Innovative Research (SBIR) Technology of the Year Award for its development of A New Ultra Fast, Low-Cost Method of Producing Aerogels. This research was funded with assistance from three NASA and one Department of Energy Small Business Innovative Research (DoE SBIR) programs. Finally, it was feasible to produce large quantities of aerogel products at a reasonable price. Another important breakthrough was the development of aerogel boards, molded shapes, and flexible blankets. Previously, aerogels were only available as a powder or a very fragile monolithic solid.

This development is significant because aerogels boast six material property records among solids—

Lowest Thermal Conductivity	10~15 m W/M-K
Lowest Dielectric Constant	1.008
Lowest Refractive Index	1.002 ~ 1.160
Lowest Density	0.001 g/cc
Highest Specific Surface Area	1200 m^2/g
Lowest Speed of Sound	70 m/sec

These properties have important implications for commercial and military applications. Because of its low thermal conductivity, it is an ideal insulating material. Silica based aerogels are already being used in many applications such as cryogenic tanks and clothing for space and arctic environments. Its low dielectric constant could

Figure 2. Aerogel insulated extreme weather jacket

enable computers to become faster by allowing designers to put components closer to each other on a chip.

The low density of aerogel materials and their thermal properties also make them ideal for reducing infrared (IR) signatures of military aircraft while adding very little weight. Man portable air defense systems (MANPADS) represent a very significant threat to all aircraft because they are widely proliferated, relatively easy to use, highly portable and lethal. Because of this IR guided threat, operations below 15,000 feet were severely limited in Kosovo and other recent conflicts. The main IR signature sources on current aircraft are the exhaust plume and any hot metal components. While atmospheric absorption significantly reduces the IR signature of the exhaust plume at long ranges, the signature of the hot metal is still susceptible to IR guided weapons. If the hot metal surfaces can be effectively shielded, the aircraft will have a very small IR signature beyond 5,000 feet. This could restore the vast majority of the battlespace that has been lost due to the MANPAD threat.

Figure 3. Aerogel board (left) and flexible aerogel blanket (right).

The Army (AATD, Fort Eustis) awarded a contract to Aspen Systems and Bell Helicopter in 2000 to begin development of an aerogel IR shield for rotorcraft. The program was co-funded by JTCG/AS starting in 2001 as part of the tri-service Aerogels for Retrofitted Increase in Aircraft Survivability (ARIAS) program. The goal of the Army led effort is to develop and evaluate the effectiveness of aerogel filled honeycomb panels and aerogel flexible blankets at moderate temperatures. A second part of the ARIAS program, led by the U.S. Navy (NAVAIR Weapons Division, China Lake), is to develop a higher temperature aerogel IR shield for hot metal surfaces. After the higher temperature IR shield is successfully demonstrated, the U.S. Air Force (46th Test Wing, WPAFB) will begin to develop an aerogel IR shield for the exhaust nozzle, or turkey feathers, of a turbojet fighter.

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Space Survivability Information Support

by Mr. Kevin Crosthwaite

The third annual Air & Space Protection Workshop held in Albuquerque, New Mexico at Kirkland AFB on 29–30 August 2001 provided an excellent forum for information exchange between the space and aircraft survivability communities. Presentations were shared on respective problems, threats, methodologies, technologies, and approaches that each community uses to enhance the survivability of their systems. One of the air vehicle survivability assets that was presented to the space community was the support that an Information Analysis Center (IAC) organization can provide.

What is an IAC?

There are currently 13 IACs serving various scientific and technical specialties. Each of these IACs is charged with gathering scientific technical information (STI) relevant to their respective technical field. Upon data collection, the IAC then processes, analyzes, and disseminates the data. These 13 IACs are all directed and funded through the Defense Technical Information Center (DTIC). The IACs are staffed and operated by contractors under a DTIC contract. They are individually sponsored by their respective technical communities. Each IAC can readily add onto their contract a related Technical Area Tasks (TATs), to provide specific support for other agencies.

SURVIAC is an example of what an IAC can do to support a technical community. SURVIAC's technical area of expertise encompasses survivability and weapon lethality. Aircraft, tanks, and ships are included within the SURVIAC scope. Survivability of spacecraft also falls under the SURVIAC charter, however, little work has been done in this area to date.

SURVIAC responds to thousands of inquiries related to survivability each year. They distribute hundreds of standardized products that they have prepared. SURVIAC also distributes a set of Government approved models and provides user support and training. They also assist the model managers in tracking changes and maintaining configuration control. SURVIAC has an active outreach program with a newsletter (the *SURVIAC Bulletin*), frequent conference participation, workshop displays, and presentations. SURVIAC has a large and successful TAT program. The TAT funding actually dwarfs DTIC's "core" funding of the IAC. The TATs enable SURVIAC staff to stay "on the cutting edge" of analysis, testing, and technology developments in their technology area. Key TATs span live fire testing, analysis, and quick reaction technical support.

SURVIAC maintains a large reference library for automated searches. There is also a repository for data on combat incidents as well as test results. This information resource is readily available to any requestor in the DoD and R&D communities.

SURVIAC is sponsored by the JTCG/AS and the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME). SURVIAC's headquarters is located at Wright-Patterson AFB, near Dayton, Ohio.

With the active support of the sponsoring communities, SURVIAC has grown to play a central, integral role within the survivability and lethality communities.

What a Space IAC Could Do

Like current IACs, a space IAC would be a common data collection point. Examples of data that could be held include satellite orbital data, launch schedules and payload, space debris distribution and size, and information on spacecraft threats from man-made threats to the natural environment. Once the common data collection point is established, the IAC becomes a natural distribution point. Users from throughout the space survivability community would be able to come to the IAC to answer their data needs as a "one-stop shop." Data that is distributed could be standardized for ease in communication throughout the community. As the IAC develops a list of key users, the IAC could also serve as a central notification point to quickly get information out to the community. The IAC could also distribute models that the community selects to standardize.

The IAC would build a subject matter expert (SME) database for quick referrals of technical questions. The IAC could also help to promote space community events—symposia, new technology discoveries, and report findings. They could also establish and host training courses for workshops on particular "hot" topics of special interest to the community.

Regarding the status of a space related IAC, there has been an effort to lay the groundwork for a SPACEIAC. In the meantime SURVIAC does have a charter for a specific niche of spacecraft survivability. Whatever evolves as a space IAC, a key issue will be the sponsorship. The sponsor needs to provide infrastructure, financial support and direction. That direction will dictate how broad or narrow a charter the IAC will work towards. Another key issue will be how to structure the IAC to allow commercial access to the data. This is essential since the majority of satellites are now operated by commercial entities. Once these issues are resolved, then the IAC can make strides to build its data collection, model suite, and SME contacts. A space related IAC would then surely grow into an integral, productive part of the space community, just as other IACs have done within their respective fields.

Mr. Kevin Crosthwaite is Director of the Survivability/Vulnerability Information Analysis Center (SURVIAC). He has worked on several technical analysis and test programs involving a wide variety of weapon systems. Mr. Crosthwaite has an M.S. in nuclear physics from Ohio State and is a licensed professional engineer. He serves on the ADPA Combat Survivability Executive board and on the AIAA Survivability Technical Committee. He may be reached at 937.255.4840, DSN 785.4840, or via E-mail at crosthwaite_kevin@bah.com.

Commercial Space System Survivability

by Dr. Joel E. Williamsen

Military space systems, used for command, control, communication, and observation, are vital to the defense strategy of the U.S. However, commercial space systems are also important components of this strategy. During the Bosnian conflict, 60 percent of military communications went through commercial space systems. While figures are still out for the Afghan conflict, it is certain that commercial space communication and observation elements were (and are still) being heavily utilized, including all of the Ikonos (commercial observation satellite) imagery of Afghanistan.

Threats to space systems, their communication links (uplinks, downlinks, and crosslinks), and their ground systems—kinetic threats, directed energy, jamming, and sabotage (especially to ground elements) are numerous, and detailed in the Rumsfeld Commission report. The technology certainly exists for enhancing space system survivability (often called space protection) through shielding, redundancy, stealth—many of the elements utilized for enhancing air system survivability. However, space systems are extremely limited in how much mass can be expended on these improvements, and survivability specialists often find their addition a "hard sell" to program managers (again, similar to air systems).

As difficult as it is to convince military space system developers and managers of the necessity for increasing space system survivability, it is even more difficult to convince commercial space system operators of this requirement. The business case for installing survivability improvements—that is, the payoff in revenue for expenditures on survivability improvements is not clear—or at the very least, has not been made clear to commercial space. This is especially true because military use of commercial space systems in the past have represented only a small fraction of the business base for the use of commercial space systems. The conventional wisdom is that there are no ways to convince the commercial space industry to incorporate improvements in spacecraft survivability, thus reducing the risk of our military using them in conflict.

There is another school of thought, however…based also in the "business case". Whereas commercial space telecommunication volume has increased tenfold over the last ten years, fiber optic landlines have increased in traffic volume by a thousandfold over the same period. Clearly, telecommunication corporations (national and international) have invested in the reliability of fiber optics in preference over space-based systems. As vital as space systems are to the military, they are becoming more marginal to telecommunications service providers. And this means that for the first time, the developers of space systems may have a reason to feel "squeezed"—their future business case may depend increasingly on national and international government supports.

Several vital questions need to be explored—

1. What is the actual risk of using commercial space systems as a vital part of our national defense?
2. What are the ways that commercial space can be convinced compensated to participate in a national and international strategy for reducing this risk?

Understanding risk is based on having insight into two critical areas—likelihood of failure and consequences of failure. Understanding the likelihood of failure requires the development and distribution of analytical tools that predict how well space systems react to threats. Understanding the consequences of failure requires that the military begin finding ways to track how commercial space is utilized—commanders' videoconferencing, troop communications, personal E-mails, ordering supplies—and how this would change under various levels of operational tempo.

It is important to approach the issue through a mindset of "understanding the present risk," not through a direct attempt to impose arbitrary design requirements on commercial space. It is possible that legislative means, such as tax incentives for firms that participate in risk assessments as part of service contracts with our government, may help establish workable mechanisms for understanding risk.

Will commercial space, with its capability to provide a communications infrastructure on demand anywhere in the world, to any area of conflict, actually be there when it's needed? Possibly, but only if a dialogue is opened between commercial space developers/opera-

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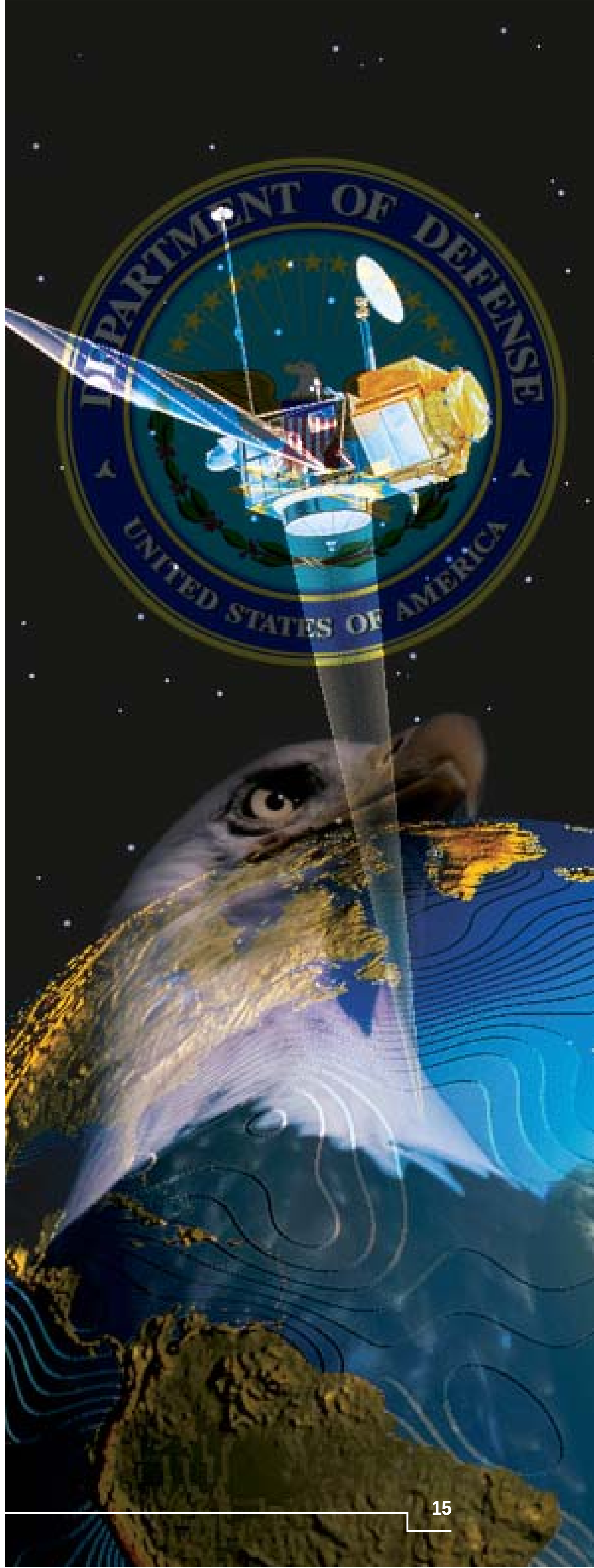

Robert E. Ball

by Ms. Barbara Honegger

If there ever was a Norman Rockwell moment for a Naval Postgraduate School professor, this was it. With the whole world focused on aircraft security, the pioneer of aircraft combat survivability education stood quietly at attention on a stage at the Naval Postgraduate School November 7, 2001 listening to why he'd been chosen to receive his field's highest honor. And then it happened. NPS Distinguished Emeritus Professor Robert E. Ball, the man who taught over 3,500 Naval aviators, DoD acquisition professionals, NATO allies, and defense industry representatives how to ensure their planes make it home safely, was presented with the National Defense Industrial Association Combat Survivability Division's Lifetime Achievement Award by two admirals—one a proud former NPS student. (RADM Timothy Heely presenting award to Prof. Ball in photo above left.)The ceremony took place at the NDIA division's annual symposium, held this year at the Navy's corporate university in Monterey, California.

"You work for 24 years and—all of a sudden—it all comes together," Ball said the day of the award. "One of your students, who's risen to admiral, returns 'home' and gives you a lifetime achievement award. It doesn't get any better than that."

Leaders from the military, academia and industry lined up to pay tribute to the soft spoken mentor who, after all these years, revealed to rousing laughter that he "really doesn't enjoy flying all that much."

"Professor Ball is one of those rare individuals who have made an incredibly positive difference," said award co-presenter Rear Admiral. Timothy L. Heely, a naval aviator and former student of Ball's who now heads research and engineering for the Naval Air Systems Command. "Thirty years ago, combat survivability was hardly even a concept and we all thought there wasn't a threat we couldn't fly around, or under. But Prof. Ball saw there was a critical need and took the bull by the horns. He both literally and figuratively 'wrote the book' on this new field and wouldn't let it die. Because of that, the men and women of the sky owe our very lives to you, Bob, and we thank you."

"Professor Ball's contributions to aircraft survivability have been of great and lasting benefit to this nation and to the Department of Defense," agreed Rear Admiral Robert H. Gormley (USN, Ret), Chairman of NDIA's Combat Survivability Division who co-presented the award with Heely. "His work has had a major impact, and I have personally been a beneficiary."

"One of the things Bob and I would say to each other over the years was that one of the reasons we were doing what we were doing was that, someday, one of his students would rise to admiral and be in a position to really make a difference with this knowledge and expertise," said Dale Atkinson, recipient of the same NDIA award in 1999 whom Ball credits with being his own mentor. "So having a student here who did just that—Admiral Heely—especially co-presenting the award, really made Bob's and my day."

"Bob Ball is 'the best of the best,'" Atkinson added. "As a result of his unparalleled efforts and contributions in this area, aircraft combat survivability is today recognized as a key military aircraft design discipline essential to overall combat mission effectiveness. Bob is also absolutely ***the*** best teacher I have ever known. We all owe him a great debt of gratitude."

"It's a tremendous honor to be recognized for a lifetime of accomplishment, especially in what began not that long ago as a completely new discipline," Ball said after thanking his family, his NPS students, the Naval community, industry, and DoD's Joint Technical Coordinating Group/Aircraft Survivability (JTCG/AS) for decades of support.

It all started back in Vietnam, when the U.S. military experienced an unexpectedly large number of aircraft losses.

"It wasn't until we started analyzing why we were losing so many planes in Southeast Asia that aircraft survivability began to be taken seriously as a design discipline—designing survivability in from the beginning," Ball said in an interview following the ceremony. "For this to become firmly established, I realized we needed to first have a strong educational program, so in 1977 I created aircraft combat survivability as a 'magnet' course, which students couldn't get anywhere else. And where better to teach that course than the Naval Postgraduate School, where hundreds upon hundreds of military officers who will become program managers in aircraft design receive their graduate education? It was humbling to teach aircraft survivability to these naval aviators—and there are none finer than naval aviators—many of whom had just come from seeing action and being shot at. I learned from them. They had the patience to teach me as much as I taught them."

Navy Captain William Cavitt, military assistant for electronic warfare systems for the Director, Operational Test and Evaluation, Office of the Secretary of Defense, is another of Ball's aircraft combat survivability students who experienced this robust faculty-student synergy unique to the Naval Postgraduate School

"By far, Professor Ball's class in aircraft survivability was the most useful and memorable of all the courses I took at NPS," Cavitt said. "He was a truly great mentor, and what he taught me I now use every day, in setting up electronic warfare operational tests so they'll be maximally relevant."

"Professor Ball's name is synonymous with the field of aircraft survivability," emphasized Dr. Steven Messervy, JTCG/AS chairman and assistant program executive officer for aviation systems engineering at Redstone Arsenal in Alabama. "Through his research, writing, and teaching over a quarter century, he codified the body of knowledge that has been, and continues to be, used by aircraft designers, pilots, leaders, and aircraft subsystem engineers worldwide. He wrote the 'bible' on this area of research in the aviation community, The Fundamentals of Aircraft Combat Survivability Analysis and Design [American Institute of Aeronautics and Astronautics (AIAA), 1985]."

With a Masters and Ph.D. in structural analysis from Northwestern University, Ball joined the NPS faculty in 1967. He established AIAA's Survivability Technical Committee in 1989, and received the society's Survivability Award in 1995. In 1991, Ball served as the chairman of the National Research Council's Committee on Weapons Effects on Airborne Systems, which reviewed the Office of Secretary of Defense's Live Fire Test and Evaluation Program. Last year, he received the DoD DDOT&E/LFT Art Stein Memorial Cup for Excellence, for outstanding contributions to and lifetime achievements in live fire testing. And in 1997, Ball was called as an expert witness for the National Transportation Safety Board's Public Hearing on the TWA Flight 800 mishap.

A significantly expanded and updated second edition of Professor Ball's textbook on aircraft combat survivability will be published by the AIAA next this year.

Editors note: *We are very happy that Professor Ball received the NDIA Lifetime Achievement Award for Survivability because the JTCG/AS has had a long and mutually rewarding relationship with Professor Ball for many years, sponsoring him to write two versions of the textbook as well as to put on the one week survivability short course numerous times over the years. He is one of our own. Congratulations Bob!*

Ms. Barbara Honegger is Senior Military Affairs Journalist with the Naval Postgraduate School Public Affairs Office, and a Navy Public Affairs Specialist.

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tors/service providers and the Military. This dialogue will be difficult to establish—there is a great deal of distrust between these "reluctant bedfellows" due to commercial space's perception that their proprietary designs and operational protocols will not be protected. The University of Denver is interested in helping to break this logjam through the Commercial Space Infrastructure Assessment Center (ComSIAC)—now in operation—as an "honest broker" to find solutions to this important national issue.

Dr. Joel Williamsen is the Director of the Center for Space Systems Survivability and the ComSIAC at the University of Denver (www.comsiac.com), and is the chair-elect of the Survivability Technical Committee of the American Institute of Aeronautics and Astronautics. He may be reached at jowillia@du.edu. To find out more about space and air survivability, contact the AIAA STC Web site at www.aiaa.org/tc/sur/index.html.

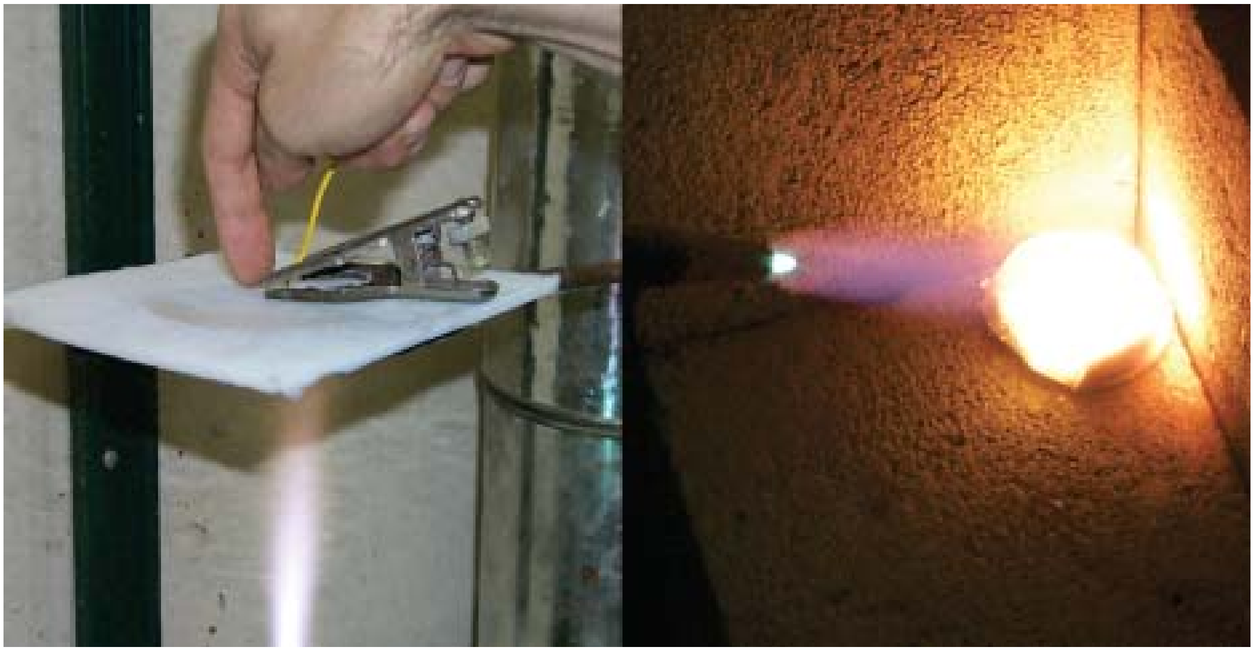

Figure 4. Oxyacetylene torch test for an aerogel blanket (left), ultra high temperature aerogel, with no damage after a 10 minute torch test (right).

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Aerogels have other properties that could significantly increase the survivability of future aircraft. In addition to their thermal qualities, they also have the ability to absorb kinetic energy. Even though they are brittle, the collapse of the solid structure occurs very slowly because their density is so low and they absorb a large amount of energy for their weight and volume. Also, when they are impacted, the gas inside the aerogel is forced out the narrow pores and a considerable amount of energy is absorbed due to the frictional forces. These effects cause the force of the impact to be reduced and spread over a longer period of time, which results in a much lower ultimate load. Aerogels could also potentially be part of a radar absorbing material (RAM). Because aerogels have a dielectric constant very near that of air, there is no appreciable reflection from the surface. Aerogels could also be specifically doped to obtain a tailored Electro-Magnetic (EM) response. In theory, a very lightweight coating could reduce the IR signature, absorb radar energy, and function as an energy absorbing structure in the event of a kinetic impact. Although it is impossible to predict exactly how aerogels will influence our lives, it is certain that aerogels have an exciting future after languishing in the laboratory for over 70 years

Dr. Truett is a project engineer with the USAF 46th Test Wing's Aerospace Survivability Flight. He currently part of the fire and explosion suppression team and also involved with emerging technologies including spacecraft survivability and directed energy weapons. Dr. Truett received his B.S. and M.S. degrees in aerospace engineering from the Georgia Institute of Technology and his Ph.D. from the University of California, San Diego. He may be reached at Leonard.Truett@wpafb.af.mil

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Rethinking Safety and Survivability

by Dr. Lowell H. Tonnessen

In this article, I'd like to revisit a theme that was featured in *Aircraft Survivability* nine years ago—the potential synergy between system safety and survivability.

Safety and survivability share a common goal—reducing losses of aircraft and user personnel. Some things can be done best by the survivability community, some by the safety community, and some by a Joint coalition. What we don't want are gaps, inefficiencies, and inconsistencies.

I found it refreshing to read the Winter 2000 issue of *Aircraft Survivability*, which highlighted the topic of space survivability. The space survivability community has not made an artificial distinction between combat survivability and survivability in the harsh, but natural, environment of space. They seem to have no difficulty in applying the term "survivability" to both parts of the problem. Orbital debris is treated quite naturally as a space survivability issue. Why is it, then, that we in the aircraft survivability community have defined "survivability" so narrowly that it excludes damage from bird strikes?

In many respects, the space survivability community is learning from a relatively mature aircraft survivability community. In one respect, though, I'd like to see the aircraft community take its lead from the space community. We should address all potential sources of damage to the aircraft and its users, whether or not the damages can be traced to hostile human action. We should adopt an intuitive layman's definition of survivability: "Living to fight another day."

A Spectrum of Scenarios

The traditional distinction between safety and survivability is highly compartmentalized. Safety addresses non-combat events, while survivability addresses only combat-induced events. Increasingly, this distinction has become blurred as we consider scenarios in which enemies of the U.S. might attack both civilian and military aircraft, at home or abroad.

Figure 1 represents some of the possible scenarios associated with the core issues of "loss of aircraft" and "personnel casualties." There likely will be points of difference among our readers as to which scenarios fall in the domain of safety versus combat survivability. We also might not agree on who has organizational responsibilities for addressing the various scenarios. The main point of the figure, however, is to demonstrate that now, more than ever, there is a greater need for closer coordination between the safety and survivability communities.

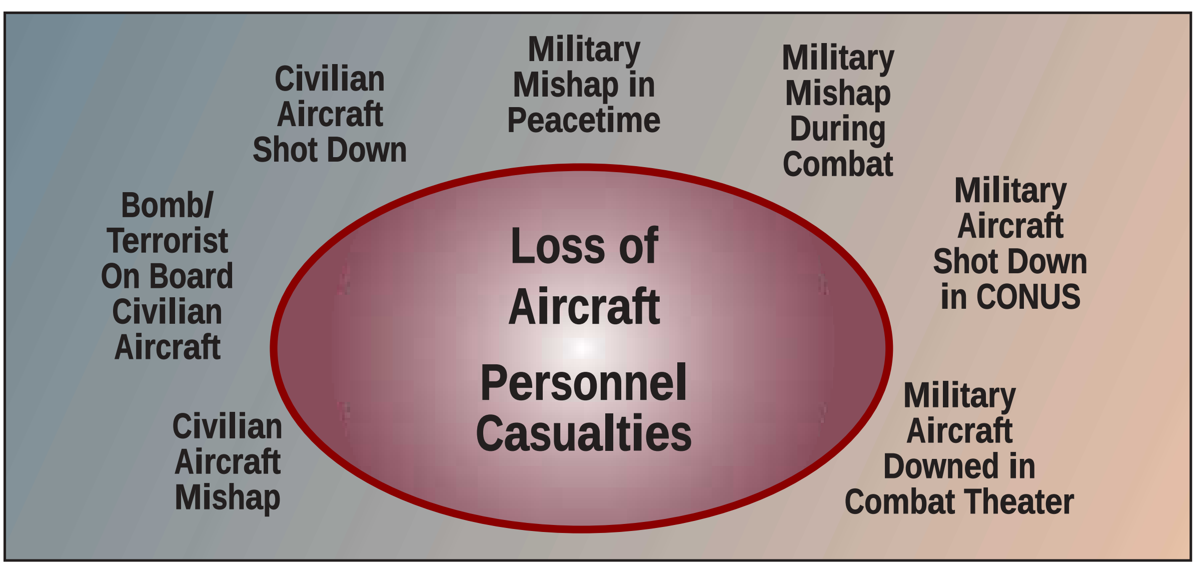

Figure 1. The Survivability Spectrum

> …the PM shall address personnel survivability issues including…the integrity of the crew compartment; and provisions for rapid egress when the system is severely damaged or destroyed.
>
> DoD 5000.2-R, C2.8.5.4

Figure 2. Crashworthiness as a Survivability Issue

In the early stages of an incident investigation, we might not even know whether an aircraft has been downed because of a safety problem, or because of a threat weapon. Only after careful investigation, for example, was it possible to determine whether the crashes of TWA 800 and AA 587 were threat related or safety related.

Personnel Casualties

One of the major obstacles to a safety-survivability coalition is the historic separation of management responsibilities. With limited funding, organizations have focused on the unique elements of their domain. This has resulted, for example, in a reluctance of the survivability community to fully address casualties, which have always been an important part of safety.

Traditionally, the safety community has had a balanced emphasis on both aircraft and personnel survival. The combat survivability community, on the other hand, has addressed aircraft survival almost exclusively. Crew casualties have been assessed primarily as critical components as they contribute to the aircraft as a system.

For example, survivability assessments provide estimates of vulnerable areas or probability of aircraft kills, but do not provide separate estimates of the number of casualties or the cause of casualties.

This has been a concern of the Office of the Director, Operational Test and Evaluation (DOT&E), which has been working with the JTCG/AS to more directly address personnel casualties in its methodologies.

Crashworthiness

Crashworthiness can be a consideration in combat or peacetime, because the cause of the crash could be either safety related or the result of a threat impacting the aircraft. Until recently, I had considered crashworthiness primarily as a safety concern, almost synonymous with "crash safety." I was somewhat surprised, therefore, when I was told that many in the safety community consider crashworthiness to be a survivability consideration. It appears crashworthiness has fallen between the cracks of survivability and safety. DOT&E, with support from the Institute for Defense Analyses, has been exploring areas where crashworthiness can improve combat survivability, and vice versa.

The purpose of crashworthy design includes the saving of lives, in addition to reducing aircraft losses (see Figure 2). Consequently, it is difficult for crashworthiness to be justified by focusing on dollars alone, without consideration for the intrinsic value of a saved life. Crashworthiness will not be given its full consideration in cost-benefit studies until personnel casualties are treated as an explicit measure of worth.

Because a primary benefit of crashworthy design is the safety of the people on board, crashworthiness is especially important to air-

Figure 3. "Tear Down the Wall"

craft without ejection systems, such as helicopters, tilt-rotor, and transport aircraft.

Potential Synergies

I'm sure that both the safety and survivability communities, and particularly specialists in low vulnerability, feel that they are not as effective as they would like to be in influencing aircraft design. What I am proposing is that both the safety and survivability communities can become more effective if priority is given to initiatives that would benefit both.

Calvin Coolidge is credited with saying, "we cannot do everything at once, but we can do something at once." Here are a few things that we in the survivability community can begin to do now, in coalition with the safety community, to better address aircraft and user survivability—

- Give increased visibility to personnel casualty issues
- Give greater priority to test and evaluation activities that might benefit both safety and survivability
- Strengthen arguments for incorporating design features that benefit both combat and peacetime survivability
- Ensure that Failure Modes and Effects Criticallity Analyses adequately account for failure modes revealed during mishap investigations
- Identify common resource needs, such as facilities and test articles
- Advocate that cost-benefit studies and Analyses of Alternatives (AOAs) adequately account for survivability benefits in combat and peacetime
- Improve combat data collection by learning from techniques and procedures used in the investigation of flight mishaps (e.g., flight data recorders, voice data recorders, interview techniques, data base design)

In the Summer 2000 issue of *Aircraft Survivability*, Mr. James O'Bryon challenged us to "tear down the wall" between safety and combat survivability (see Figure 3). I encourage you to re-read the Winter 1993 and December 1989 issues of *Aircraft Survivability* to determine whether we've made progress toward that goal in the last decade. I think you'll recognize many changes for the better, but you'll also be challenged by potential synergies that remain unrealized. Let's work so that, 10 years from now, others can detect the progress we've made.

Dr. Lowell Tonnessen is a Research Staff Member and Project Leader for Live Fire Test and Evaluation at the Institute for Defense Analyses. He looks forward to comment, feedback, and continued discussion of these issues at 703.845.6921, or by E-mail at ltonness@ida.org.

The Joint Live Fire Program

by Mr. Jeffrey Wuich

The Joint Live Fire (JLF) Program was chartered by the Office of the Under Secretary of Defense, Director Defense Test & Evaluation (OUSD/DDTE), as a Joint (Air Force, Army and Navy) Test and Evaluation (JTE) Program in 1984. The purpose of the JLF Program is to test and evaluate "fielded" U.S. systems (air, land, and sea) and U.S. weapons against actual foreign threats and foreign targets (air, land and sea) encountered in combat (i.e., "better to sweat in peace, than to bleed in combat").

The original four objectives of the JLF Program have not changed. They are to—

1. Gather empirical data on the vulnerability of U.S. systems to foreign weapons and the lethality of U.S. weapons against foreign targets
2. Provide insight into design changes necessary to reduce vulnerabilities and improve lethalities of U.S. weapon systems
3. Enhance the database available for battle damage assessment and repair
4. Validate/Calibrate current vulnerability and lethality methodologies

The JLF Program continues today under the leadership of the Office of the Deputy Director, Operational Test and Evaluation/Live Fire Testing (DOT&E/LFT), which also oversees the congressionally mandated Live Fire Test (LFT) Program for U.S. systems and U.S. weapons in the "acquisition" process. DOT&E/LFT provides test execution funding and provides technical and financial oversight. The JTCG/AS and the JTCG for Munitions Effectiveness (JTCG/ME) are the executive agents for the JLF program, while the Services execute and support the tests under joint leadership. JLF has three components that are used to address air, ground and sea systems.

JLF/Air

The Aircraft Systems component of JLF (JLF/Air) has, and continues to test aircraft such as the Air Force's C–130, F–15 and F–16; the Army's AH–1S, AH–64, CH–47 and UH–60; and the Navy's AV–8B, F–14 and F/A–18. Threats tested against these aircraft include small arms/automatic weapons (SA/AW), anti-aircraft artillery (AAA), surface-to-air missiles (SAM) including man-portable air defense systems (MANPADS), air-to-air missiles (AAM) and directed energy weapons (DEW). JLF/Air is also responsible for conducting tests to evaluate the lethality of fielded U.S. air-to-air munitions such as the Sidewinder air-intercept missile (AIM–9) and the 20mm PGU-28/B SAPHEI projectile against foreign fixed and rotary-wing aircraft. In recent years, JLF/Air has begun to address the issue of MANPADS against U.S. aircraft, in support of the warfighter. A number of tests utilizing MANPADS threats against U.S. aircraft have been completed.

JLF/Ground

The Armor, Anti-Armor/Ground Mobile component of JLF (JLF/Ground) began as the Armor/Anti-Armor effort to address the vulnerability of U.S. Army and Marine Corps armored systems such as the M1 Abrams, M60, and M48 main battle tanks; M2/M3 and LAV 25 fighting vehicles; M113 personnel carrier; and AAVP–7 landing craft to foreign threat munitions. Battle Damage and Repair (BDAR) processes and techniques were institutionalized during these early JLF/Ground tests and lessons learned continue today. JLF/Ground also focuses on the lethality of the U.S. large caliber tank-fired, medium caliber auto-cannon, and the anti-tank guided missile against former Soviet Union armored platforms including main battle tanks and the BMP series of fighting vehicles. In 1998, the scope of JLF/Ground was expanded to include all ground mobile systems including air defense systems, surface-to-surface missile launchers, and logistics vehicles. Besides expanding the suite of platforms and munitions addressed, JLF/Ground conducts tests to supports the Air Force in developing requirements for munitions lethality and fosters international collaboration on selected programs.

JLF/Sea

The Sea Systems component of JLF (JLF/Sea) was initiated in FY01 with initial funding received in FY02. JLF/Sea will address the vulnerability of fielded surface and submarine combatants including attack gun-boats and will also address the lethality of fielded U.S. threats against foreign sea systems. Like its predecessors (JLF/Air and JLF/Ground) experience gained and lessons learned from JLF/Sea vulnerability and lethality test programs will be utilized for designing more survivable U.S. sea systems and more lethal U.S. sea weapons in the future. This information will also be utilized for mission planning, warfighter tactics, techniques and procedures.

JLF—Making a Difference—Impact on Next-Generation U.S. Systems and Weapons

While JLF does not and never was intended to replace, or fund, Congressionally mandated LFT of developmental systems and munitions, a key feature of the JLF Program has been the sharing of data and test resources with the development community. For example, lessons learned from structural evaluations conducted following JLF/Air tests conducted on the AV–8B, F–15, F–16 and F/A–18 wings and empennages, particularly the composite assemblies, are being directly applied to the F/A–18E/F, F–22, and the Joint Strike Fighter (JSF). Similarly, lessons learned from JLF/Air post-test evaluations of fuel systems, propulsion, flight controls, crew stations and munitions stowage are being factored into newly designed fixed and rotary-wing systems, including the F/A–18E/F, F–22, JSF and Comanche helicopter. Data collected and lessons learned from JLF/Air lethality test programs are being applied to the development of the AIM–9X as well as to future 20mm projectiles being developed by the U.S. Army (e.g., Comanche Gun System), U.S. Navy (e.g., PGU–28 A/B projectile) and U.S. Air Force (e.g., 20mm replacement projectile).

JLF/Ground vulnerability tests, beginning with the M113, M2/M3, and M1 Abrams, concentrated on identifying parameters influencing platform vulnerability and crew casualties. These tests demonstrated the value of compartmentalization of stowed ammunition for large caliber rounds as well as medium caliber cartridges and anti-tank guided missiles. Stowage of hazardous materials, in general, and of ammunition, in particular, was shown to have a major impact on damage and damage mitigation. These tests demonstrated the importance of fuel tank/fuel line location, fire suppression system design and layout, spall liners, electrical system redundancy, the elimination of brittle materials for mechanical components, and combat overrides for critical fire control and weapon firing safety devices. Lessons learned from JLF/Ground tests have been applied to the systems tested as well as to next generation systems. From the viewpoint of munitions development, results from ongoing JLF/Ground tests of fielded U.S. weapons against foreign targets have been shared with ammunition designers of new and/or improved weapons during engineering and manufacturing design to allow them to improve their designs prior to MS III (now MS C). These tests have also been used to generate full-up system lethality data for candidate off-the-shelf munitions being considered for lethality upgrades to Army and Marine Corps fighting vehicles. More specifically, these tests have given munition designers insight into tandem warhead parameters affecting defeat of explosive reactive armor. Similarly, tests of kinetic energy penetrators against actual armor installations have provided key insights into post-perforation damage mechanisms as well as penetration performance.

Impact on Vulnerability Reduction Technologies

The focus of JLF is on fielded systems, but the program has included leveraging with "proof-of-concept" vulnerability reduction technologies—as long as their use does not interfere with the original objectives of the JLF Program. JLF/Air Test Programs have leveraged "proof-of-concept" technologies such as reactive fuel tank fire and explosion suppression systems, engine nacelle fire detection and extinguishing systems and reactive hydraulic fluid flow-sensing shut-off valves. Data collected and lessons learned from these tests demonstrate that significant fuel fire/explosion and hydraulic system protection is feasible for both "fielded" and "future" fixed and rotary-wing aircraft systems. JLF/Air tests utilizing MANPADS missiles against U.S. aircraft were leveraged with the FBI to obtain data that would be useful in forensic investigations of terrorist missile attacks. These same tests are being used to help identify vulnerability reduction technologies that may be effective against the MANPADS threat.

JLF/Ground has encouraged leveraging its test programs to obtain data of interest to other elements of the RDT&E community. For example, impact signatures of munitions attacking armor platforms during day, night, and obscured visibility conditions as they appear to the naked eye and through platform sights collected during JLF tests have proven useful for training and battle damage assessment. Comparisons of platform signatures from before and after damage have also been used to develop battle damage assessment procedures. Data have been collected inside and near target vehicles to determine radiation levels and contamination due to depleted uranium munitions.

Impact on Modeling & Simulation

The value of testing complemented with modeling has been demonstrated through years of JLF test experience. Modeling is used to support test planning and design by eliminating shots producing no useful information and extending test results to conditions not tested. Test results, on the other hand, are invested in model development and are key to system-level model validation. As part of the effort to address the MANPADS threat, DoD and industry aircraft vulnerability experts meet on an annual basis to review and discuss—

- Existing MANPADS damage prediction methodologies which can be used for vulnerability reduction design; warfighter tactics, techniques, and procedures; and mission planning
- How to enhance these methodologies utilizing test data from completed and future JLF/Air MANPADS tests.

When applicable, the JLF Program leverages their tests in support of JTCG/AS and JTCG/ME modeling and simulation related efforts.

JLF Contributions to Military Operations

During DESERT STORM JLF/Ground test data provided soldiers crucial information on the lethality of specific munitions against specific targets. JLF munitions lethality tests provided critical insights into the combat effectiveness of various anti-armor munitions. During DESERT STORM, JLF/Air was called upon to investigate the vulnerability of F–15 and F–16 aircraft carrying extended-range external fuel tanks (i.e., could the warfighter enter the combat zone carrying empty and potentially explosive external fuel tanks?). JLF/Air was very responsive to the warfighter's need. JLF/Air personnel were able to complete a thorough test program within 30 days to address this issue. Test results and recommendations on how to proceed were provided to Air Combat Command in support of the warfighter, prior to the completion of the air campaign. Aircraft battle damage assessment and repair (ABDAR) techniques and technical order (T.O.) repair limits verified and validated during the JLF/Air Program were invaluable to ABDAR technicians during Operation DESERT STORM. In fact, upon returning from DESERT STORM, a number of the ABDAR technicians interviewed placed great value on the realistic training they had received from participating in the JLF/Air Program.

In Summary

Knowledge gained and lessons learned from the JLF Program have helped to reduce U.S. casualties in DESERT STORM (Kuwait/Iraq), Operation ALLIED FORCE (Kosovo) and the current campaign against terrorism—Operation ENDURING FREEDOM (Afghanistan). Prior to entering combat, the U.S. Military can continue to test its fielded systems and munitions against the ever-changing threats and weapon systems they will face in combat through the JLF Program. Knowledge gained and lessons learned prior to combat will not only help reduce U.S. "high-value" system losses, it will more importantly reduce U.S. Military and innocent civilian casualties, while maximizing the losses for our enemies.

Author's Note: *The author would like to acknowledge inputs received from Messrs. Dennis Bely, Lex Morrissey, John Murphy, Steve Polyak, Al Wearner, Tracy Sheppard, Larry Eusanio, and Dale Atkinson for this article. Their inputs are greatly appreciated.*

SURVIAC is tasked to provide data management support to the JLF Program Office and serve as the JLF data repository. SURVIAC assists in establishing data reporting guidelines to assure uniformity in planning, data collection and data processing. SURVIAC also assists in revising/updating JLF documents. If you'd like to learn more about the JLF Program, or wish to review test data and lessons learned, you can contact Mr. Jeffrey Wuich (SURVIAC/Booz Allen Hamilton), who may be reached at 937.255.4840, extension 259 or via E-mail at jeffrey.wuich@wpafb.af.mil.

Mr. Live Fire Retires

by Mr. Tracy Sheppard

Galileo and the telescope. Newton and gravity. Maxwell and electromagnetism. O'Bryon and Live Fire. Some things just go hand-in-hand. But since the only constant is change, all things must pass. Effective November 30, 2001, Mr James. F. O'Bryon retired from a distinguished career of over 30 years with the Federal civil service.

Jim began his federal career as an U.S. Army enlisted man in the mid-1960s. While serving in uniform he worked at the Ballistic Research Laboratory (BRL) at Aberdeen Proving Ground, Maryland. Following his Military service, Mr. O'Bryon remained on staff at BRL and was responsible for, among other efforts, computing ballistic range tables for artillery munitions. From BRL he moved to the U.S. Army's Materiel Systems Analysis Activity (AMSAA) where he advanced to become a branch chief and headed the Red-on-Blue Working Group of the JTCG/ME (a group over which he exercised financial and technical oversight as Director of Live Fire in the Pentagon). In 1986, Jim moved south to the Pentagon where he became Director of Live Fire, then under the Office of Acquisition and Technology. The position to which Jim entered was created by Congress in part as a result of the controversial and very public Army live fire test of the Bradley Fighting Vehicle System. Through Mr. O'Bryon's leadership, the office of Live Fire took form and content and has since become bedrock for ensuring that the systems and platforms that make their way onto the battlefield are thoroughly tested and evaluated, and that our uniformed Service members have the most lethal and most survivable equipment available to any fighting force on earth. One does not need to look far to find combat examples of the valuable work undertaken by the Live Fire office under Jim's leadership.

Jim was born in Schenectady, New York and schooled at the Massachusetts Institute of Technology and George Washington University. He has undergraduate and advanced degrees in electrical engineering, operations research, and management science. Jim has authored over 60 technical publications and owns several copyrights. His honors include the NDIA's Gold Medal, Who's Who in America, Outstanding Young Men in America, Sigma Xi, and he is a distinguished lecturer at the Defense Systems Management College and at the Center for Studies in Acquisition at the University of Texas at Austin. He is a fellow of the Center for Advanced Engineering Study at MIT and is Chairman of NDIA's Test and Evaluation Division.

In retirement Mr. O'Bryon should have the opportunity to indulge himself in those activities he enjoys not related to the Defense Department. He is a songwriter and recording artist with four albums to his credit and has been a vocalist and instrumentalist at various church and community functions. Jim has an active concert schedule and is a conference speaker on mathematics, education, music, and the patent/copyright process. He continues to serve on the Boards of a charitable trust in Connecticut, a seminary in New York, a Foundation in Colorado and is an active member of the MIT Education Council. Jim and his wife Adina reside in Bel Air, Maryland. They have four children. We wish Jim the very best in his retirement and we thank him for a job well done on behalf of past, present, and future uniformed military personnel of the United States of America.

Tracy Sheppard is the Technical Director of the Washington Office of the Center for Strategic Analysis, University of Texas (UT) at Austin. Prior to joining the research faculty of the University of Texas, Tracy served for over 15 years within DoD, first as a Marine and then in positions at Aberdeen Proving Ground and within the office of the Deputy Director for OT&E/LFT in the Pentagon. Tracy received his AS and Bachelor of Electrical Engineering degrees from the Johns Hopkins University in Baltimore, Maryland.

MANPADS

Ballistic Test of a Helicopter Composite Generic Tailboom

by Mr. Nicholas J. Calapodas

Rotorcraft are particularly susceptible to ground threats due to their low altitude operation and the relatively low gauge of their airframe structural components as compared to fighter and fixed wing transport aircraft. In recent years, proliferation of MANPADS has become a major concern for rotorcraft survivability. There is little to no experience in the rotorcraft industry regarding how to design structures to survive MANPADS threats and little to no test data to support such designs. The Army's planned Survivable Affordable Repairable Airframe Program (SARAP) program will be addressing design issues to lower vulnerability against large High Explosive, Incendiary (HEI) and MANPADS threats. The JTCG/AS Advanced Survivable Rotorcraft Validation Program, V–2–03, is integrated with the SARAP program to foster rotorcraft-MANPADS survivability. Furthermore, the results obtained from the recently completed JTCG/AS Advanced Survivable Rotorcraft Program, V–0–02, indicate that the probability of kill (PK) is dramatically reduced if the MANPADS threat explodes a short distance away from the aircraft.

The objective of the present program was to determine the effect a MANPADS proximity hit would have on a composite tailboom structure typical of mid-gross weight rotorcraft. The tailboom structure used in this test was residual property of a previous U.S. Army R&D program with Boeing Helicopters that was co-funded by the Aviation Applied Technology Director-ate (AATD) of the U.S. Army Aviation & Missile Command (AMCOM) and JTCG/AS. The goals in that program were to develop a low cost and lightweight structure without mechanical fasteners capable of surviving 23mm HEI ballistic damage and to reduce the weight and cost by 15 percent and 25 percent respectively using early 1990's technology as a baseline. A cylindrical composite structure was designed that was six feet long and two feet in diameter, representing the aft end of the tailboom of a typical gunship helicopter. The design loads of an existing gunship helicopter were used. The tailboom specimen configuration is shown in Figure 1(see page 28).

Four tailboom specimens were fabricated by Automated Dynamics Corporation (ADC) under sub-contract to Boeing Helicopters, using the IM7/PEEK thermoplastic material system and the in-situ fabrication process. All tailbooms had six hat-type stiffeners and four "C" frames; however, two tailbooms had 10-ply skins and two had 16-ply skins. All components were made of IM7/PEEK. This material system was selected because thermoplastics typically exhibit a higher bond strength than thermoset materials. Furthermore, thermoplastics allow simultaneous fiber placement and consolidation, known as the in-situ fabrication process, which has the potential to reduce fabrication cost. Although the PEEK thermoplastic resin system is not widely used in the rotorcraft industry at present, in the early 1990's it was considered as a system with great potential. The IM7 fiber is widely used with toughened thermoset epoxies. The MANPADS damage inflicted on this realistic tailboom specimen sheds light as to what magnitude of damage can be expected.

Under the earlier program, three tailboom specimens were subjected to 23 mm HEI ballistic and high energy slew laser testing. The damage resulting from the laser testing was insignificant although the external temperature reached 2300°F. For the ballistic test, the selected impact point was at an intersection of skin, frame and stiffener, which is a worst case scenario. The typical ballistic damage was characterized by delamination between the stiffeners and the skin caused by the explosion and

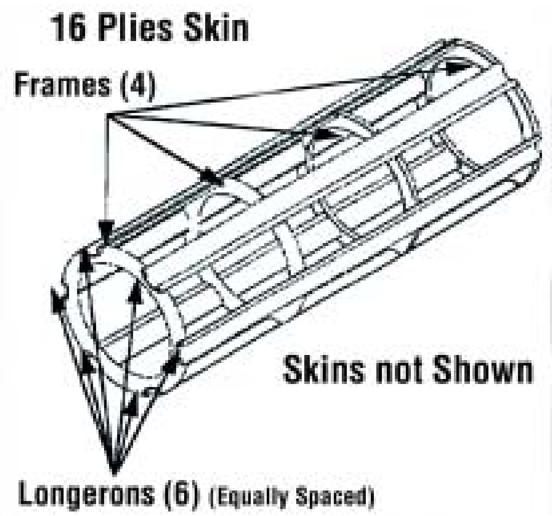

Figure 1. Tailboom

Figure 2.. Ultimate-to-failure Static Test

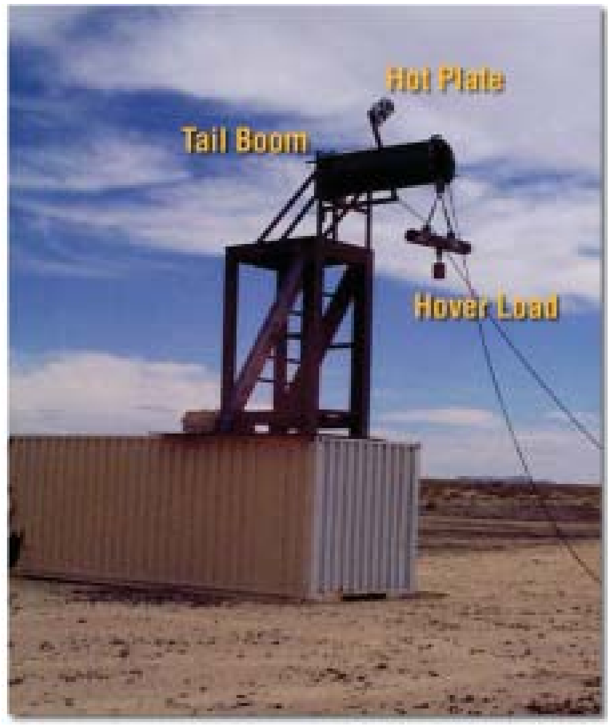

Figure 3. MANPADS Test Set-Up

was limited to approximately 12 inches on either side of the frame as measured from the impact point. Also, the skin separated from the frame (due to backpressure) at approximately a 120 degree arc on the projectile entrance side. In the subsequent static, fatigue, and ultimate-to-failure testing the tailbooms were judged to have survived the ballistic damage and carried much higher than "fly home" loads before skin buckling failure occurred. Failure initiated where the projectile base

Figure 4. Side View of Damaged Tailboom

Figure 5. Exterior View Looking Aft

Figure 6. Interior View Looking Aft

punctured the tailboom. A typical failure is shown in Figure 2.

Since the tailboom specimens had successfully survived 23 mm HEI damage, it was decided to subject the remaining 16-ply skin tailboom to MANPADS testing under the present program. Testing was performed by the Weapons Division at the Naval Air Warfare Center, China Lake, California. The tailboom MANPADS test set-up is shown in Figure 3.

An 850 pound load was suspended from the aft end representing hover load. Since the tailboom is cylindrical, the direction of the load is not important. The center of the two element hotplate that provided the target for the infrared (IR)seeker on the missile was two feet away from the surface of the tailboom, at approximately the 10 o' clock position looking forward, and approximately two feet forward of the aft end.

The results are shown in the Figures 4 through 6. It is highly doubtful that a relatively small structure, such as the tailboom, could have survived a direct hit. Since the damaged tailboom continued to hold the hover load, a forced landing could be possible; however, its residual strength to carry "fly home" loads is unknown and the damage that would have been inflicted on the tail rotor drive shaft might have disabled the tail rotor.

The results from a recently completed JTCG/AS program and other work performed in the technical community in the Z-Pin and/or stitching technologies indicate considerable increase in the pull strength of composite laminates.

These findings and the MANPADS test results suggest that structural "hardening" of rotorcraft composite structures could substantially mitigate MANPADS damage.

Endnotes

1 Caravasos, N., Freno, R., Luzetsky, R., Damage Tolerant Thermoplastic Composite Tailboom Structures, USAATCOM TR 96–D–40, December 1996

2 Calapodas, N., Rubinsky, J., Ballistic Tolerant Rotorcraft Stiffened Panels with ZPin Reinforcement, USAAMCOM TR–D–15, December 2001.

Mr. Nicholas J. Calapodas received his B.S. and M.S. in Aerospace Engineering from the University of Kansas. He is a research and test engineer at the Aviation Applied Technology Directorate, AMCOM, Fort Eustis, Virginia. He has 28 years of experience in structures, structural dynamics, and survivability. He is a member of the JTCG/AS Vulnerability Subgroup, Structures and Materials Committee, and he may be reached at 757.878.1472 or ncalapodas@aatd.eustis.army.mil.

Combat Survivability Division Presents Annual Survivability Awards

by Mr. John Vice

The National Defense Industrial Association's Combat Survivability Awards for Leadership and Technical Achievement were presented to Mr. James M. Sinnett and Mr. Alan R. Wiechman, respectively, at the Aircraft Survivability 2001 Symposium held November 5–8, 2001 at the Naval Postgraduate School (NPS), Monterey, California. These awards, presented annually at the symposium, recognize individuals or teams demonstrating superior performance across the entire spectrum of survivability, including susceptibility reduction, vulnerability reduction, and related modeling and simulation. In addition to these annual awards, the NDIA Combat Survivability Award for Lifetime Achievement was presented to Dr. Robert E. Ball, Professor Emeritus of the NPS.

Leadership Award for Combat Survivability

The NDIA Leadership Award for Combat Survivability is presented to a person who has made major contributions to enhancing combat survivability. The individual selected must have demonstrated outstanding leadership in enhancing the overall discipline of combat survivability, or played a significant role in a major aspect of survivability design, program management, research and development, modeling and simulation, test and evaluation, education, or the development of standards. The emphasis of this award is on demonstrated superior leadership of a continuing nature.

Mr. Sinnett, retired Vice President Phantom Works Strategic Development, The Boeing Company, St. Louis, Missouri, was the 2001 recipient. Mr. Sinnett was cited for his contributions to the enhancement of aircraft survivability through leading the development of next-generation survivability technologies within The Boeing Company and throughout the military aircraft industry as a whole. Mr. Sinnett directed large research and development investments for which there was, at the outset, little assurance of a positive return. These included far-reaching classified technology demonstrations, the successful completion of which elevated the Boeing team to a position of leadership in the industry. Under Mr. Sinnett's enlightened and strong leadership, the Boeing Phantom Works has attained a position of prominence in low observable (LO) technology. The talented core group he nurtured continues to ensure that the U.S. maintains its significant lead in aircraft combat survivability technologies and is acknowledged as an invaluable national defense resource.

Technical Achievement Award for Combat Survivability

The NDIA Technical Achievement Award for Combat Survivability is presented to a person or team who has made a significant technical contribution to any aspect of survivability. It may be presented for a specific act or contribution or for exceptional technical performance over a prolonged period. Individuals at any level of experience are eligible for this award.

Mr. Wiechman, Director, Signature Design and Applications, The Boeing Company Phantom Works, St. Louis, Missouri, was the 2001 recipient. Mr. Wiechman was recognized by his contemporaries as a pioneer in LO aircraft design, a giant whose work to date has given the United States a legacy of improved survivability and influenced an entire generation of combat vehicles. His career in LO design began at the Lockheed Skunk Works where, working on a number of classified programs, including Have Blue, the F–117, and Sea Shadow, he was a principal figure in introducing a powerful new survivability tool— signature reduction. In those early days, nothing was certain. Designs were born through lessons learned from practical experience—personally applying radar absorbing materials, spending countless hours at dark radar test ranges, attending to implementation of each design element. Because of Mr. Wiechman's pioneering work, the U.S. gained a 15-year lead over potential adversaries that it has not relinquished, and the effectiveness of his designs and products has been thoroughly proven in combat operations.

Combat Survivability Lifetime Achievement Award

Unlike the annual Leadership and Technical Achievement Awards, the NDIA's Combat Survivability Award for Lifetime Achievement is presented only when merited by lifetime contributions of a noteworthy individual to the long-term enhancement of aircraft survivability and national security. Such a worthy individual was recognized at the 2001 Aircraft Survivability Symposium. The Combat Survivability Lifetime Achievement Award was presented to Dr. Ball, Professor Emeritus of the Naval Postgraduate School, Monterey, California.

Dr. Ball has been an important force working to establish survivability as an aircraft design discipline. He was among the first to note that aircraft losses during the Vietnam War were heavily influenced by aircraft design. Recognizing that survivability considerations should be given more attention during the system design process, he had the insight to recognize that formal education could play a beneficial role and provide engineers with the tools needed to design more survivable aircraft. As a consequence, he developed and gained approval for the first ever college-level course on aircraft survivability, which was incorporated into the regular aeronautical engineering curriculum at the U.S. Naval Postgraduate School in 1977. He also developed a short course in aircraft survivability fundamentals suitable for presentation in a non-academic setting. By the time he retired from the U.S. Naval Postgraduate School, some 4,000 individuals from Government and industry had benefited from his courses, as have engineers and military officers in other countries–Canada, Greece, the United Kingdom and at NATO headquarters (see Pioneers of Survivability on page 16).

Mr. Alan R. Wiechman receives the 2001 NDIA Technical Achievement Award for Combat Survivability from RADM Robert H. Gormley, USN (Ret), Chairman, NDIA Combat Survivability Division.

Accompanied by RADM Timothy L. Heely, Assistant Commander for Research and Engineering, Naval Air Systems Command, Patuxent Tiver, Maryland, Dr. Robert E. Ball receives the NDIA Combat Survivability Award for Lifetime Achievement from RADM Robert H. Gormley, USN (Ret), Chairman, NDIA Combat Survivability Division.

James M. Sinnett receives the 2001 NDIA Leadership Award for Combat Survivability from RADM Robert H. Gormley, USN (Ret), Chairman, NDIA Combat Survivability Division.

Mr. D. Jerry Wallick, Chairman, Awards Committee, Combat Survivability Division, Mr. Alan R. Wiechman, Mr. James M. Sinnett, Dr. Robert E. Ball, and RADM Robert H. Gormley, USN (Ret), Chairman, NDIA Combat Survivability Division (L to R).

calendar of events

APR

6–8 — San Diego, CA
Advanced Technology Electronic Defense Conference Recognizing and Defeating World Threats
Contact: Jack Kress, 812.330.1800
http://ateds.crane.navy.mil

9–10 — APG, MD
JLF Aircraft Systems Mid-Year Review Planning Meeting
Contact: Steve Polyak, 410.278.3605

16–19 — Cambridge, MA
Course: Aircraft Fires & Explosions Accident, Combat, and Terrorist Attacks
Contact: Albert Moussa, 617-661-0700
amoussa@blazetech.com
www.blazetech.com

22–25 — Denver, CO
43rd AIAA/ASME/ASCE/AHS Structures, Structural Dynamics, and Materials Conference
www.aiaa.org

29 — Albuquerque, NM
Halon Options Technical Working Conference
Contact: Dr. Richard Gann, 301.975.6866, rggann@nist.gov
www.bfrl.nist.gov/866/HOTWC

30 – 3 May — AFB, FL
2002 Threat, Warhead and Effects Seminar
SECRET/NOFORN only
Contact: SSgt Evelyn Roman-Amador 937.327.2381
Evelyn.Roman-Amador@ohspri.ang.af.mil

MAY

6–10 — Montery,CA
National LFT&E Workshop
Contact: Sam Campagna, 703.247.2544
www.ndia.org

JUN

17–19 — Norfolk, VA
11th Annual Executive Forum on Modeling and Simulation
Contact: Program & Agenda: Larry Alexander, 703.824.3404, lalexander@ndia.org
Registration: Kerry Davison, 703.247.9471, kdavidson@ndia.org
www.trainingsystems.org/events/index.cfm

25–28 — Colorado Springs, CO
Joint Model Users Meeting (JMUM) 2002
Contact: SURVIAC, Paul Jeng, 937.431.2712

Information for inclusion in the Calendar of Events may be sent to:

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FAX: 703.289.5467

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